3-15-1952

Input and Output Relationships in Livestock Production

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AGR. ECON. PAMPHLET 38 January 1952

INPUT AND OUTPUT RELATIONSHIPS IN LIVESTOCK PRODUCTION

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and

Bureau of Reclamation

United States Department of the Interior

Cooperating

Brookings, South Dakota

2661 14

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INPUT-OUTPUT RELATIONSHIPS IN LIVESTOCK PRODUCTION [1] [2]

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I. INTRODUCTION

What are the profitable patterns of crops and livestock for areas in Central South Dakota? [3] This is a question that farmers in South Dakota are especially concerned with at the present time. The farmer is always faced with the problem of planning the most profitable farm organization and operation, but the problem at the present time is emphasized by the current action programs in irrigation and soil conservation which stress the need for more legumes and livestock in the farm organization. If the economist is to aid the farmer and the action programs, an insight to the question posed above must be sought.

The budgeting technique is one of the economic tools of analysis that is used to determine the most profitable farm organization and operations for irrigation and soil conservation farming. This technique involves a rigorous economic analysis of alternative farm organizations and alternative methods of production.

1/ Cooperative project of the South Dakota Agricultural Experiment Station, Project number 179r - 798 Supplement No. 5, and the Bureau of Reclamation, U. S. Department of the Interior.

2/ The author acknowledges valuable criticism from his Colleagues in the Agricultural Economics Department and from Mr. Everett Jennewein and other staff members of the Bureau of Reclamation. Special acknowledgments are due to R. A. Cave and W. A. Goodbary of the Dairy Department, L. B. Embry, W. C. McCone, R. F. Wilson, and K. Rasmussen of the Animal Husbandry Department, and C. W. Carlson of the Poultry Department for aid given in interpreting experimental data and adjusting this data to fit farm conditions.

3/ The data presented in this report, particularily those data which concern inputs from pasture, are applicable only to central South Dakota.

Although the budgeting method is useful in an economic analysis of income potentials, the budget is no better than the information upon which it is based. The purpose of this paper is to relate the physical input of feed to the physical output of livestock products in such a way that the most economical level of feeding can be determined by budget analysis.

A range of physical input-output data is necessary for a comprehensive economic analysis[4] The data should be sufficiently complete to show the relationship between input and output at several levels of production and to show the economically important rates of input substitution. Although there may be an optimum input in terms of physical efficiency, the most profitable level and method of production is dependent upon the price relationship of the input factors (feed) and the price relationship of the input to the output of livestock products.

Review of Input-Output Data

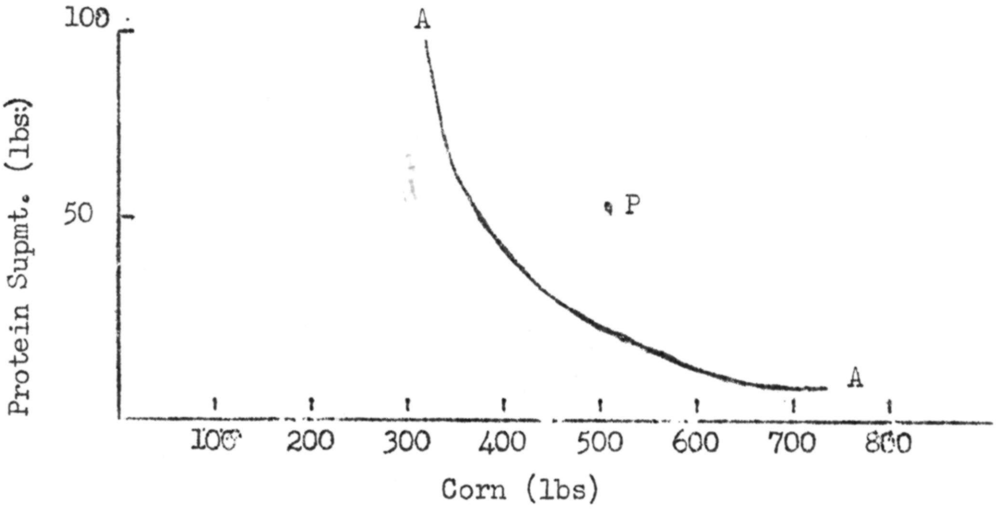
Farm management specialists have often used average input and average output. When they do this they are using the arithmetic mean of several quantities and qualities of inputs and the arithmetic mean of the corresponding outputs in their budgeting work.

This type of input-output relationship is open to question in two respects. Firstly, the arithmetic mean of different qualities

4/ Ernest J. Nesius, "Some Problems of Joint Use of Theory and Emperical Data in Farm Management Research", Journal of Farm Economics, Vol. 32, No. 4, November 1950, pp. 1178-1179. See also Irving F. Fellows, "Developing and Applying Production Functions in Farm Management", Journal of Farm Economics, Vol. 31, No. 4, November 1949, pp. 1058-1060.

of inputs may give a relationship which is different from those indicated in experiments or individual farm records. For example, on the basis of experimental data for raising hogs from an initial weight of 30 pounds to a market weight of 200 pounds it is known that the feed required for producing 100 pounds of gain in drylot is of the general nature shown in figure I. Curve AA represents the alternative combination of protein and corn that can be used

Figure I.



in producting 100 pounds of gain and is a regression of experimental data on levels of protein feeding. If the average input were calculated (i.e., the arithmetic mean of the corn and the arithmetic mean of the protein) the input may well be point "P". The exact position of "P" would depend upon the distribution of the individual cases, i.e., the number of cases at each of the various protein levels. With any given distribution, the average input-output relationship (point "P") would be different from the individual relationships.

This difference is due to the imperfect substitutabilities of input factors[5].

Secondly, "average" physical data do not lend themselves to an economic analysis. If average data are used, the economic analysis in budgeting is limited to that of determining the most profitable farm organization with a given (average) method of production. It is conceivable that the method of production may have more effect than the farm organization on net farm income, and therefore should be subjected to an economic analysis in the budgeting process[6].

An infinite variety of possible input-output relationships arise from differences in levels and combinations of inputs. This poses important problems in selecting for analysis the sets of relationships that are believed to affect significantly the efficiency of farms. Some of the inputs which have little effect on the efficiency of the farms may not warrant the time required for a determination of the most profitable relationship. In the case of livestock feeding, however, the physical data should be subjected to an economic analysis since feeding is of great importance in the farm operation. Feed costs represent 50 to 90 per cent of the costs in livestock production. Moreover, on many farms in South Dakota a large portion of the farmers's income is obtained from livestock and livestock products.

5/ For a more complete discussion see I. F. Fellows, "The Application of Static Economic Theory to Farm Management Problems", Journal of Farm Economics, p. 1103, Vol. 32, No. 4, November 1950.

6/ H. R. Tolley, J. E. Black, and M. J. B. Ezekiel, Input as Related to Output in Farm Organization and Cost-of-Production Studies, U. S. D. A. Dept. Bul. 1277, 1924.

Possible Sources of Input-Output Data

Input-output data for livestock production may be obtained either from farm records, surveys or experiments. Many farm management specialists prefer the farm record method for obtaining input-output data since this data is considered to be more representative of farm conditions. The input-output relationships which are obtained from experimental studies are usually more efficient than those found on farms. This is especially true if the average of the experimental data are compared with average data obtained from farm records since the quality of animals, feeds, and management is usually superior in experiments. Even though the experimental data are similar to data secured from farm records in terms of quality of the animals and feeds, the relationships obtained from experimental data are more efficient. This difference in efficiency is due, in the main, to the supervised feeding and other management factors which are attendant to experimental studies.

A serious disadvantage of data obtained from farm records is that it is difficult to measure the effect of changing the level of feeding or quality of ration. For example, in dairying, factors other than feed, such as the inherent producing capacity, affect the annual production. Farm record data do not usually give information on the basic producing capacity of the cows. In analyzing a set of farm records, it is difficult to ascertain how much of the variation in production is due to variations in ration, level of feeding, inherent producing capacities or management.

Input-output data obtained from experiments shows more clearly the effect of the quality of ration and level of feeding since other factors which affect production can be controlled in the experiment. Although most of the experiments have been conducted with rations which are superior to those found on farms, several have been conducted with inferior rations. This gives a range of data which is similar to the many different qualities of rations fed on farms. Since the efficiency of transformation in experiments is superior to those on farms because of the supervised feeding, superior management, and other conditions that are found in experiments, the entire range of data has to be adjusted to fit farm conditions. Farm record data can be useful in making these adjustments. Further help can be obtained from production specialists who are familiar with the livestock practices of the area.

Procedure Used

The input-output data presented in this paper were obtained from experiments on livestock feeding. All available experiments on different rates of feeding and qualities of rations were examined to secure a range of data. The production specialists in the dairy, animal husbandry, and poultry departments assisted in interpreting the results of the experiments. Further aid was obtained from the production specialists in adjusting the experimental results to farm conditions as they exist in Central South Dakota. This adjustment to Central South Dakota conditions was especially necessary where pasture is a part of the ration.

II. INPUT-OUTPUT RELATIONSHIPS IN FEEDING DAIRY COWS

Input-output data for dairy feeding should indicate the physical relationship between feed input and butterfat product at several levels of concentrate feeding. The dairyman has many alternatives in regard to levels of feeding. These alternatives range from feeding only roughage to feeding as much concentrates as the animal will consume.

Many input substitutions are possible in dairy feeding. For example, good pasture may be substituted for poor pasture and some grain, good legume hay may be substitued for poor hay and some grain, oats may be substituted for corn, protein for carbonaceous concentrates, etc. Time does not permit a presentation of all of these input substitutions. Consequently, estimates on the rates of substitution were made for input alternatives which were considered most important economically. The substitution of different pasture qualities for grain was considered to be the most important1/.

Although a definite relationship exists between feed input and butterfat production, Willard's study indicates that the inherent producing capacity of the cow is an important factor which affects annual butterfat production2/.

The fallacies which arise from a failure to recognize the

1/ The reason for considering the pasture and grain substitution more important economically than the hay and grain substitution is that a wider range of the substitution appears to be associated with the pasture-grain substitution. See tables IXa and IXb in F. B. Morrison's, Feeds and Feeding, Ithaca, N. Y., The Morrison Publishing Co., 20th Ed., 1946, pp. 1032 and 1033.

2/ H. S. Willard, Grain vs No Grain for Dairy Cows, Wyoming Agr. Expt. Sta., Bul. 202, 1934, pp. 10-11.

importance of the inherent producing ability in presenting physical relationships is made quite clear in input-output data secured by Ashe from farm records[3]. For example, his study indicates that if 1700 pounds of grain are fed per year, the annual milk production will be less than 6500 pounds; if the grain fed per year is increased to 4531 pounds, the annual milk production will increase to 10,500 or more. In contrast controlled dairy experiments indicate that a cow which produces 6500 pounds of milk annually, when fed 1700 pounds of grain, will produce approximately 7800 pounds of milk annually when the grain is increased to 4500 pounds. On the other hand, cows which will produce 10,500 pounds of milk on 4500 pounds of grain, will produce approximately 7800 pounds of milk on 1700 pounds of grain[4]. This comparison seems to indicate that the relationships secured by Ashe greatly over-estimate the influence of feed on milk production, and emphasizes the importance of considering the factor of inherent producing capacity in presenting input-output data.

It is impossible to calculate input-output relationships for all the different inherent producing capacities. For example, if all of the dairy cows in South Dakota were fed at a 1:4 grain-milk ratio, the annual butterfat production per cow might well range from 175 to 450 pounds.

3/ A. J. Ashe, Input-Output Relationships in Milk Production From New York Cost Account Farms, New York Agr. Expt. Sta., A. E. 705, 1949, p. 4.

4/ E. Jensen, et al., Input-Output Relationships in Milk Production, U. S. D. A. Tech. Bul 815, 1942, p. 42. R. R. Graves, et. al., Feeding Dairy Cows on Alfalfa Hay Alone, U. S. D. A. Tech. Bul. 610, 1938, pp. 21-28. L. W. Mosley, et al., Dairy Work at the Huntley Field Station, Huntley, Montana 1918-1927, U. S. D. A. Tech. Bul. 116, 1929, p. 20.

An infinite number of producing abilities exist within this range. For practical purposes, as far as budgeting is concerned, it is not necessary to estimate relationships for many of these inherent levels. Particular levels can be chosen to represent low, medium and high producers. This method is a considerable improvement over the method which assumes that the inherent factor is of no consequence.

Estimates on annual feed requirements for different levels of production for low, medium, and high producing cows in South Dakota are given in tables 1, 2 and 3. At each level of production, estimates have been made on hay and grain requirements for three different types of pastures.

Three inherent producing abilities were selected for estimating input-output relationships. These producing capacities can be classified as low, medium and high producing dairy cows in Central South Dakota. Assumptions underlying this classification are: low producing cows will yield an annual butterfat production of 275 pounds at a 1:4 grain-milk ratio on good hay and good pasture; medium producing cows will yield an annual butterfat production of 325 pounds at a 1:4 grain-milk ratio on good hay and good pasture; and high producing cows will yeild a butterfat production of 385 pounds at a 1:4 grain-milk ratio on good hay and good pasture. The selection of these particular inherent levels is somewhat arbitrary except for the medium level which conforms quite closely with the average production and average feed inputs of dairy herds in the South Dakota Dairy Herd Improvement Association. The selection of levels for low and high producers is based upon the relationship among low, medium and high producers of other states[5].

The estimates on input-output relationships for the three different types of producing capacities are based upon Jensen's input-output study[6]. In this experiment the inherent producing capacity of the cows was known at the outset of the study, thus allowing the measurement of relationship between grain feeding and milk production. Although the dairy cattle used in Jensen's experiment cannot be considered representative of dairy cattle in South Dakota, and conditions of the experiment cannot be considered comparable to farm conditions, the diminshing return relationship between grain inputs and milk outputs is of considerable importance in estimating production under farm conditions.

At each level of production, estimates of hay and grain requirements were made for three different types of pastures. The types of pastures used in this analysis were (1) excellent, irrigated pasture, (2) good brome-alfalfa dryland pasture, and (3) fair native dryland pasture. Pasture studies indicate that the amount of T.D.N. obtained annually from pastures depends upon (1) rate of stocking (2) persistency of luxurient growth, and (3) intensity of growth, i.e., the area that

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5/ Unpublished data on grain-forage substitution in milk production, Michigan and Indiana.

6/ E. Jensen, et al., op. cit. p 42.

animals have to cover to obtain fill[7]. The last two mentioned factors cause considerable variation in the amount of T.D.N. obtained annually from the three types of pastures. From review of pasture studies and suggestions from dairy production specialists, the amount of T.D.N. obtained annually per cow was estimated to be 2550 pounds for irrigated pastures, 1950 pounds for brome-alfalfa dryland pasture, and 1200 pounds for fair native dryland pasture. This assumes that the cows are pastured 150 days annually beginning May 15th. The average T.D.N. obtained per day was estimated to be 17 lbs. for irrigated, 13 for brome-alfalfa dryland and 8 for fair native. These daily averages are valid only if the cows are pastured 150 days. For example, the average daily T.D.N. consumption on fair native pasture would be much higher due to the lush growth in the spring of the year if the pasture period were shortened to, say 75 days.

7/ R. R. Graves, et al., Feeding Value for Milk Production of Pasture Grasses When Grazed, When Fed Green, and When Fed as Hay or Silage, U. S. D. A. Tech. Bul. 381, 1933; R. R. Hurt, et al., Will More Forage Pay? U. S. D. A. Misc. Pub. 702, 1949, pp. 18-19; idem, Milk and Butterfat Production by Dairy Cows on Four Different Planes of Feeding, U. S. D. A. Tech. Bul. 724. 1940, pp. 3, 16, 17; S. R. James, and P. M. Brandt, Irrigated Pastures for Dairy Cattle, Oregon Agr. Expt. Sta. Bul. 264, 1930; F. B. Morrison, Feeds and Feeding, Ithaca, N. Y., The Morrison Publishing Co., 21st Ed. 1949, pp 948, 1187-1188; L. H. Rich, et al., Efficiency Studies of Utah Dairy Pastures, Utah Agr. Ext. Serv. Bul. 188, 1949; H. S. Willard, Roughage Feeding of Dairy Cattle, Wyoming Agr. Expt. Sta. Bul. 237, 1940, pp. 4-6; idem, Grain vs No Grain For Dairy Cows, Wyoming Agr. Expt. Sta. Bul. 202, 1934, pp. 17-19.

Table 1. Rations for Feeding Low Producing Dairy Cows 1/

Annual Production		Annual T.D.N. from Grain and Forage			
Butterfat (lbs)	Milk (lbs)	Grain TDN 2/ (lbs)	Hay TDN 3/ (lbs)	Silage TDN 4/ (lbs)	Total TDN (lbs)
Fair Native Dryland Pasture - 1200 TDN Annually					
150	4285		2750	935	4885
200	5714	886	2664	935	5685
225	6428	1618	2367	935	6110
235	6714	1909	2296	935	6340
245	7000	2581	1924	935	6640
255	7285	3548	1359	935	7040
Good Brome and Alfalfa Dryland Pasture - 1950 TDN Annually					
175	5000		2750	935	5235
200	5714	235	2565	935	5685
225	6428	803	2422	935	6110
235	6714	1160	2295	935	6340
245	7000	1748	2007	935	6640
255	7285	2632	1523	935	7040
Excellent Irrigated Brome and Alfalfa Pasture - 2550 TDN Annually					
200	5714		2200	935	5685
225	6428	400	2225	935	6110
235	6714	654	2201	935	6340
245	7000	1180	1975	935	6640
255	7285	1931	1624	935	7040

1/ Basic producing ability of cow 235# B. F. at 1:4 grain-milk ratio on good hay and pasture, 305 day lactation period, Holstein cows, 1200 lb. wt., 3.5% fat, fall freshening.

2/ Grain ration should contain 11.5% digestible protein.

3/ Good hay - consisting of a high proportion of legumes harvested at an immature stage. Amounts cited in table include hay wasted. The wasted roughage is estimated to be 10% of total offered.

4/ If silage is not available, good quality legume hay may be substituted for the silage at the rate of one pound of hay for 2.5 pounds of silage. Wet beet pulp may also be substituted for the silage cited in the table at the rate of two pounds of wet beet pulp for one pound of silage.

Table 2. Rations for Feeding Medium Producing Dairy Cows [1/]

Annual Production Butterfat (lbs)	Milk (lbs)	Annual T.D.N. From Grain and Forage: Grain TDN [2/] (lbs)	Hay TDN [3/] (lbs)	Silage TDN [4/] (lbs)	Total TDN (lbs)
Fair Native Dryland Pasture - 1200 TDN Annually					
239	6831		3228	1122	5550
275	7857	506	3197	1122	6025
300	8571	1328	2775	1122	6425
325	9268	2530	2648	1122	6900
330	9429	2850	2273	1122	7025
338	9714	3550	1503	1122	7375
Good Brome and Alfalfa Dryland Pasture - 1950 TDN Annually					
250	7143		2728	1122	5600
275	7857	351	2602	1122	6025
300	8571	1020	2333	1122	6425
325	9268	1981	~~2247~~ 1847	1122	6900
330	9429	2242	~~1791~~ 1711	1122	7025
340	9714	2962	1341	1122	7375
Excellent Irrigated Brome and Alfalfa Pasture - 2550 TDN Annually					
264	7551		2166	1122	5838
275	7857	203	2250	1122	6025
300	8571	602	2151	1122	6425
325	9268	1430	1798	1122	6900
330	9429	1660	1693	1122	7025
340	9714	2378	1325	1122	7375

1/ Basic producing ability of cow 325# B. F. at 1:4 grain-milk ratio on good hay and pasture 305 day lactation period, Holstein cows, 1200 lb. wt., 3.5% fat, fall freshening.

2/ Grain ration should contain 11.5% digestible protein.

3/ Good hay - consisting of a high proportion of legumes harvested at an immature stage. Amounts cited in table include hay wasted. The wasted roughage is estimated to be 10% of total offered.

4/ If silage is not available, good quality legume hay may be substituted for the silage at the rate of one pound of hay for 2.5 pounds of silage. Wet pulp may also be substituted for the silage cited in the table at the rate of two pounds of wet beet pulp for one pound of silage.

Table 3. Rations for Feeding High Producing Dairy Cows 1/

Annual Production		Annual T.D.N. From Grain and Forage			
Butterfat (lbs)	Milk (lbs)	Grain TDN 2/ (lbs)	Hay TDN 3/ (lbs)	Silage TDN 4/ (lbs)	Total TDN (lbs)
		Fair Native Dryland Pasture - 1200 TDN Annually			
350	10000	1418	2450	1215	6250
400	11429	2585	1860	1215	6950
450	12857	3962	1623	1215	8100
470	13429	4647	1448	1215	8600
475	13571	5087	1248	1215	8750
		Good Brome and Alfalfa Dryland Pasture - 1950 TDN Annually			
350	10000	1200	1885	1215	6250
400	11429	2196	1589	1215	6950
450	12857	3468	1467	1215	8100
470	13429	4120	1315	1215	8600
475	13571	4480	1105	1215	8750
		Excellent Irrigated Brome and Alfalfa Pasture - 2550 TDN Annually			
350	10000	880	1605	1215	6250
400	11429	1785	1400	1215	6950
450	12857	2974	1361	1215	8100
470	13429	3614	1213	1215	8600
475	13571	4035	974	1215	8750

1/ Basic producing ability of cow 385# B.F. at 1:4 grain-milk ratio on good hay and pasture, 305 day lactation period, Holstein cows, 1200 lb. wt., 3.5% fat, fall freshening.

2/ Grain ration should contain 11.5% digestible protein.

3/ Good hay - consisting of a high proportion of legumes harvested at an immature stage. Amounts cited in table include hay wasted. The wasted roughage is estimated to be 10% of total offered.

4/ If silage is not available, good quality legume hay may be substituted for the silage at the rate of one pound of hay for 2.5 pounds of silage. Wet beet pulp may also be substituted for the silage cited in the table at the rate of two pounds of wet beet pulp for one pound of silage.

III. INPUT-OUTPUT RELATIONSHIPS IN FATTENING BEEF CATTLE

Important factors which affect the relationships between feed and gain in fattening beef cattle are (1) the age of the animal (2) the feeding system employed (3) the degree of finish and (4) the inherent capacity of the animal to gain. All of these factors affect in varying degrees the quantity of feed required per unit of gain. Each of these four factors will be briefly discussed below.

First, different relationships between feed and gain can be expected for beef cattle of different ages 1/. On full feed calves are more efficient in terms of feed required per pound of gain than yearlings, and the latter in turn are more efficient than two year olds. These differences in efficiency of gain which exist among calves, yearlings, and two year olds are large enough to warrant separate input-output relationships for the three age groups.

Second, many different systems of beef feeding are available to the producer in planning his feeding program. The principal systems are (1) full feeding in drylot (2) various degrees of limited feeding in drylot and (3) systems of deferred feeding. The relationship between feed and gain will not be the same for each of these systems. Due to the lack of data, however, it is not possible to consider all of the possible systems in estimating input-output relationships. For example, little information is available on the relationship between feed and gain for limited concentrate feeding in drylot. Most of the experi-

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1/ C. C. Culbertson, _et al._, _Relative Efficiency of Calves, Yearlings and Two-year-old Steers for the Producer_, Iowa Agr. Expt. Sta. Bul. 271, June 1930, F. B. Morrison, _Feeds and Feeding_, the Morrison Publishing Co., Ithaca, N. Y., 21st Ed., 1949, pp. 798-800.

mental data deal with full feeding in drylot and important systems of deferred feeding.

Third, as the feeders reach a high finish, a greater amount of feed is required per pound of gain 2/. While this is of considerable economic importance and although the findings from experiments agree on the amount of feed required per pound of gain for various stages of the feeding period, they do not agree on the amount of gain or finish required to reach a particular carcass grade 3/. For example, the range in the findings on the amount of gain needed to bring choice feeder calves in drylot to a slaughter grade of choice varies from 240 to 500 pounds; the amount of gain required to bring choice feeder calves to a prime carcass grade varies from 380 to 600 pounds. Since information on the amount of gain required to bring feeders to various carcass grades is at such great variance, it is difficult to estimate a probable gain requirement. Because of this difficulty the average relationship between feed and gain for the entire feeding period, and the "average" carcass grade which would result from this feeding period will be presented. Such a presentation does not allow an economic determination of the most profitable degree of finish, but until more information becomes available on the relationship between gain and carcass grade for a particular grade of feeders, this area of economic analysis will have to be by-passed.

2/ Fred C. Francis, et al., War Time Beef Production, Illinois Expt. Sta. Bul 501, 1944.

3/ Ibid. pp. 131-132; Aaron G. Nelson, Relation of Feed Consumed to Food Products Produced by Fattening Cattle, U.S.D.A. Tech. Bul. 900, 1945; O. H. Hankins, and L. P. Brule, Relationships Among Production and Grade Factors of Beef, U.S.D.A., Tech. Bul. 665, 1938; Rex Beresford, "Can You Feed for Gain - No Margin", Successful Farming, August, 1951, p. 45.

Lastly, the inherent capacity of feeder cattle to gain rapidly and efficiently affects the relationship between feed and gain to a large extent. Winters and McMahon found that the efficiency of "good" calves in converting feed into gain ranged from 14.77 to 21.80 pounds of gain per 100 pounds of total digestible nutrients consumed; this is a difference of 7.03 pounds or approximately 50 per cent 4/. Although it is known that this variation in efficiency exists even within the same grade of feeders, the appearance of the animals is not a reliable indication of their capacity to make economical gains 5/. Consequently, the inherent capacity of the animal was not considered in estimating input-output relationships. An average efficiency for each age group will have to be used.

Studies on the efficiency of gain for different grades of feeders indicate some difference in feed required per pound of gain, but this difference is due to feeding the poorer grades of animals for an uneconomically long period 6/. If cattle are fed to a degree of finish appropriate to their grade, the efficiency of gain for each grade of feeder is approximately the same 7/.

The estimated daily gain, slaughter grade, and daily ration for fattening feeder cattle are presented in tables 4 through 8. The daily gain and the daily ration are the average for the feeding period. The average daily concentrate ration is less for the medium grade animals since this grade is fed for a shorter period which is appropriate to

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4/ Laurence M. Winters and Harry McMahon, Efficiency Variation in Steers, Minnesota Expt. Sta. Tech. Bul. 94, 1933, p. 17.

5/ Morrison, op. cit. pp. 797-798.

6/ Roscoe R. Snapp, Beef Cattle, New York, John Wiley and Sons, Inc. 1939, p. 256.

7/ Ibid. pp. 253-254.

their grade. For the feeder calves the average carcass grade at the end of the feeding period is estimated to be "good" for the medium feeders and "choice" for the good to choice feeders. For the yearlings and two-year-olds the average carcass grade at the end of the feeding period is estimated to be "good" for the medium feeders, choice for the good feeders, and prime for the choice feeders.

Rations for fattening of calves in drylot are presented in table 4. These rations are estimates based upon several studies 8/.

Full feed rations for fattening calves on pasture are presented in table 5. The full feeding on pasture system consists of two phases. The winter phase begins November 1 and ends May 15. During this period, the calves are fed a sufficient amount of concentrates to gain approximately 1.25 pounds per day. With this method of winter feeding the animals are in sufficient flesh to be finished to an appropriate carcass grade after being full fed during the grazing phase. Under this feeding system, the calves have to be fed to a heavier weight than those in drylot to reach a carcass grade comparable to calves fed in drylot 9/.

8/ The estimates on the relationship between feed and gain for fattening calves which are presented in tables 4, 5, and 6 are based primarily on the following studies: W. C. McCone, Fattening Yearling Beef Cattle on Pasture, South Dakota Agr. Expt. Sta. Bul. 407, 1951; I. B. Johnson and F. U. Fenn, Creep Feeding Calves, South Dakota Agr. Expt. Sta. Bul. 371, 1943; R. R. Thalman, Corn and Alfalfa Substitutes for Fattening Cattle, Nebraska Expt. Sta. Bul. 355, 1944; R. R. Thalman, Protein Supplements for Fattening Cattle, Nebraska Expt. Sta. Bul. 345, 1943; Marvel L. Baker, Fattening Yearling Heifers on Alfalfa Pasture, Nebraska Expt. Sta. Bul. 281, 1933; G. A. Branaman, Fattening Beef Calves, Michigan Agr. Expt. Sta. Spec. Bul. 280, 1946; W. G. Peters, Selection and Purchase of Feeders and Rations for Fattening Beef Cattle, Minnestoa Agr. Expt. Sta. Bul. 300, 193[illegible]; John A. Hopkins and Robert B. Elwood, Experience of Some Iowa Farmers with Cattle Feeding, Iowa Agr. Expt. Sta. Bul. 435, 1941.

9/ Ibid.

Another method of feeding on pasture consists of full concentrate feeding during only the latter half of the grazing period. Rations for this method are presented in table 6. The winter phase in this system is identical to the full feeding on pasture system. The grazing phase differs in that the feeders are full fed concentrates only during the latter half of the grazing period. The medium grade feeders would be full-fed concentrates for a period of 65 days and the good to choice grade feeders would be full-fed concentrates for a period of 100 days. Both the medium and the good to choice animals would have to be fed to heavier weights than on the drylot or full feed on pasture system to reach a carcass finish of good and choice, respectively 10/.

Rations for fattening yearlings in drylot are presented in table 7. Yearlings make larger daily gains than calves but less total gain is needed to bring the yearling to a finish comparable to calves. Four hundred and fifty pounds of gain is needed to bring good yearling feeders to a carcass grade of choice, while good to choice feeder calves required five hundred pounds of gain to reach a carcass grade of choice 11/.

10/ Ibid.

11/ The feed requirement and gain for yearlings are based primarily on the following studies: W. H. Peters, op. cit. p. 9; Rex Beresford, op. cit., p. 45; R. R. Thalman, Corn and Alfalfa Substitutes for Fattening Cattle, Nebraska Expt. Sta. Bul. 355, 1944; Marvel L. Baker, The Use of Native Grass in Producing Finished Cattle, Nebraska Expt. Sta. Bul. 307 1937; idem, The Use of Alfalfa and Native Grass Pasture in Producing Finished Cattle, Nebraska Expt. Sta. Bul. 315, 1938; F. L. Bentley and P. T. Ziegler, Fattening Good, Medium and Common Grade Steers, Pennsylvania Agr. Expt. Sta. Bul. 329, 1936.

Rations for two-year-olds fed in dry lots are presented in table 8. Two-year olds make larger daily gains than either calves or yearlings. The feeding period is shorter for two-year-olds and, they require less total gain to reach a finish comparable to that of calves and yearlings. However, because of the larger daily feed consumption of two-year-olds the efficiency gain is lower for two-year-olds than for calves or yearlings 12/

12/ Estimates on feed required and gain for two-year-olds are based primarily on the following studies: C. C. Culbertson, *et al.*, *op. cit.*; Rex Beresford, *op. cit.* p. 45; Fred C. Francis, *et al*; *op. cit.*; Roscoe R. Snapp, *op. cit.*; pp. 231-238.

Table 4. Rations for Fattening Calves in Drylot

Item	Grade of Feeders: Medium	Grade of Feeders: Good to Choice
Number of days fed	225	275
Initial Weight, lbs.	350	400
Final Weight, lbs.	800	950
Daily Gain, lbs.	2	2
Slaughter Grade	Good 3/	Choice 3/
Average Daily feed:		
Concentrates lbs. 1/	10.0	11.0
Protein suplmt. lbs.	.5	.5
Alfalfa Hay lbs. 2/	6.0	6.0

1/ Dried Beet pulp may be substituted for the concentrates, pound for pound, up to 50 percent of the concentrate ration. Wet beet pulp may be substituted for dried beet pulp at the rate of 8 pounds of wet pulp for 1 pound of dry.

2/ Beet tops may be substituted for alfalfa hay pound for pound. The hay requirement includes waste - estimated to be 10 percent of total offered.

3/ 1951 Grades.

Table 5. Rations for Fattening Calves Full Feed on Pasture

	Item	Grade of Feeders: Medium	Grade of Feeders: Good to Choice
	Number of days fed	195	195
Winter Phase	Initial Weight lbs.	350	400
Nov 1-May 15	Final Weight lbs.	604	654
	Daily Gain lbs.	1.3	1.3
	Average Daily Feed:		
	Concentrates lbs. 1/	3	3
	Protein Suplmt. lbs.	---	---
	Alfalfa Hay lbs. 2/	15	15
	Number of days fed	103	157
Grazing	Initial Weight lbs.	604	654
Phase	Final Weight lbs.	830	1000
	Daily Gain lbs.	2.2	2.2
	Slaughter Grade	Good 3/	Choice 3/
	Average Daily Feed:		
	Concentrates lbs. 1/	11.5	13.0
	Protein Suplmt. lbs.	.3	.3

1/ Dried Beet pulp may be substituted for the concentrates, pound for pound, up to 50 percent of the concentrate ration. Wet beet pulp may be substituted for dried beet pulp at the rate of 8 pounds of wet pulp for 1 pound of dry.

2/ Beet tops may be substituted for alfalfa hay pound for pound. The hay requirement includes waste - estimated to be 10 percent of total offered.

3/ 1951 Grades

Table 6. Rations for Fattening Calves Full Fed During Latter Half Only of Grazing Period 1/

	Item	Grade of Feeders: Medium	Good to Choice
	Number of days fed	195	195
Winter Phase	Initial Weight lbs.	350	400
Nov 1-May 15	Final Weight lbs.	604	654
	Daily Gain lbs.	1.3	1.3
	Average Daily Feed:		
	Concentrates lbs. 1/	3	3
	Protein Suplmt. lbs	---	---
	Alfalfa Hay lbs. 2/	15	15
	Number of days fed	132	198
Grazing	Initial Weight lbs.	604	654
Phase	Final Weight lbs.	855	1030
	Daily Gain lbs.	1.9	1.9
	Slaughter Grade	Good 3/	Choice 3/
	Average Daily Feed:		
	Concentrates lbs. 1/	6.2	8.0
	Protein Suplmt. lbs.	.5	.5

1/ Dried Beet pulp may be substituted for the concentrates, pound for pound, up to 50 percent of the concentrate ration. Wet beet pulp may be substituted for dried beet pulp at the rate of 8 pounds of wet pulp for 1 pound of dry.

2/ Beet tops may be substituted for alfalfa hay pound for pound. The hay requirement includes waste - estimated to be 10 percent of total offered.

3/ 1951 Grades.

Table 7. Rations for Fattening Yearlings in Dry Lot

Item	Grade of Feeders: Medium	Good	Choice
Number of days fed	170	200	227
Initial Weight lbs.	550	600	650
Final Weight lbs.	925	1050	1150
Daily Gain lbs.	2.2	2.2	2.2
Slaughter Grade	Good 3/	Choice 3/	Prime 3/
Average Daily Feed:			
Concentrates lbs. 1/	12.5	14.0	15.0
Protein Suplmt. lbs.	.75	.75	.75
Alfalfa Hay lbs. 2/	7.0	7.0	7.0

1/ Dried Beet pulp may be substituted for the concentrates, pound for pound, up to 50 percent of the concentrate ration. Wet beet pulp may be substituted for dried beet pulp at the rate of 8 pounds of wet pulp for 1 pound of dry.

2/ Beet tops may be substituted for alfalfa hay pound for pound. The hay requirement includes waste - estimated to be 10 percent of total offered.

3/ 1951 Grades.

Table 8. Rations for Fattening Two Year Olds in Dry Lot

Item	Grade of Feeders Medium	Good	Choice
Number of days fed	125	167	200
Initial Weight lbs.	750	850	900
Final Weight lbs.	1065	1250	1350
Daily Gain lbs.	2.4	2.4	2.4
Slaughter Grade	Good 3/	Choice 3/	Prime 3/
Average Daily Feed:			
Concentrates lbs. 1/	15	16	17
Protein Suplmt. lbs.	1	1	1
Alfalfa Hay lbs. 2/	9	8	8

1/ Dried Beet pulp may be subsituted for the concentrates, pound for pound, up to 50 percent of the concentrate ration. Wet beet pulp may be substituted for dried beet pulp at the rate of 8 pounds of wet pulp for 1 pound of dry.

2/ Beet tops may be substituted for alfalfa hay pound for pound. The hay requirement includes waste -- estimated to be 10 percent of total offered.

3/ 1951 Grades.

IV. INPUT-OUTPUT RELATIONSHIPS IN FATTENING WESTERN LAMBS

Three important factors which affect the rate of gain and the slaughter grade of western lambs are (1) the proportion of concentrate and roughage in the ration, (2) the quality of the concentrate and roughage in the ration and (3) the length of the fattening period. These three factors present many alternatives to the feeder in planning his feeding program. Each of these points will now be discussed.

The physically efficient lamb fattening ration is one in which the proportion of concentrates is high 1/. Production specialists maintain that a 50 to 60 percent concentrate ration is the most common in lamb feeding. The lamb feeder in planning his feeding program has the alternative, however, of feeding a ration which contains from 5 to 60 percent concentrates. For this reason it appeared appropriate to estimate the relationship between feed and gain for several rations which have different proportions of concentrates and roughage.

A direct relationship exists between the proportion of concentrates in the ration, rate of gain, and slaughter grade. Rapid gains can be expected with rations which have 50 to 60 percent concentrates. When the proportion of concentrates is reduced, especially to less than 25 percent of the total ration, the rate of gain becomes slower and more inefficient. Higher slaughter grades are also expected with the rations which have a high percentage of concentrates.

Alfalfa hay is unexcelled as a roughage for sheep feeding 2/.

1/ F. B. Morrison, Feeds and Feeding, Ithaca, N. Y., The Morrison Publishing Co., 21st Ed. 1949, p. 897.

2/ Ibid. p. 349.

Other roughage such as native hay may be substituted for alfalfa provided the percentage of protein supplement in the ration is increased. However, largely because of the protein supplement needed with the native hay ration, native hay is usually fed in rations which have a high proportion of concentrates 3/.

The rate of gain and slaughter grade is also dependent upon the length of the feeding period 4/. Approximately 30 days are required to get the lambs on full feed. The rate of gain is slow during this initial period. After the lambs are on full feed, the gains are rapid and efficient until the lambs reach a slaughter finish. The amount of gain needed to finish the lambs to a top slaughter grade is dependent upon the quality of the ration and the proportion of concentrates in the ration 5/. If a ration which contains 60 percent concentrates is fed, lambs reach a top slaughter grade after a gain of 30 pounds. Approximately 40 pounds of gain are required for top slaughter grade in the case of a 40 to 50 percent concentrate ration. Top slaughter grades are usually not obtained with rations which are low in concentrates even though the lambs are fed for a long period.

The effects of grain-forage substitution upon gain and slaughter grade are shown in table 10. Estimates were made on feed requirement, rate of gain and slaughter grade for five rations which have different proportions of concentrates and roughage. To show the effect of the

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3/ P. S. Jordan and W. H. Peters, _Feeding Methods and Rations for Lambs_, Minnesota Agr. Expt. Sta. Bul. 306, 1944, p. 15.

4/ L. B. Embry, "Protein Requirements of Fattening Lambs, the Value of Different Proportions of Hay and Silage, and the Need of Cobalt and Copper Supplementation", (Unpublished Doctor's Thesis, Cornell University, Ithaca, New York, 1950)

5/ C. C. Culbertson, _et al._, _Different Proportions of Corn and Hay in Fattening Lambs_, Iowa Agr. Expt. Sta. A. H. Leaflet No. 178, February, 1951.

length of feeding period on feed requirement, rate of gain and slaughter grade, estimates were made for each 10 pounds of gain.

The effects of grain-forage substitution when native hay is fed is shown in table 11. The feed requirement, rate of gain, and slaughter grade relationships for native hay are similar to those associated with an alfalfa ration. More protein supplements are required for the native hay rations if gains and slaughter grades are sought comparable to those obtained with an alfalfa ration.

Since sugar beet by-products may be a common feed in proposed irrigation areas, estimates were made on the value of the by-products in lamb feeding. These estimates are presented in tables 12 and 13 6/.

Experimental data on the value of beet by-products is limited, but the available information suggests that rapid gains can be obtained with a by-product ration providing the rations contain some grain and protein supplement 7/. It is estimated at least one pound of grain and .2 pound of protein supplement must be fed in the by-product ration to achieve rates and efficiences of gain comparable to those obtained with a good quality grain and alfalfa hay ration.

6/ E. J. Maynard, Beets and Meat, Denver, Col., Through the Leaves Press, 1950, pp. 19-71; Alden S. Ingraham, Utilizing Self-Feeding Methods for Fattening Lambs on Sugar-Beet By-Products and Other Home-Grown Feeds, Wyoming Agr. Expt. Sta. Bul. 257, 1942, pp. 9-16; I. B. Johnson and Lester E. Johnson, Fattening Range Lambs on South Dakota Feeds, South Dakota Agr. Expt. Sta. Bul. 373, 1944, pp. 11, 12, 16; W. L. Quayle, Fattening Lambs in Sugar Beet Districts, Wyoming Agr. Expt. Sta. Bul. 191, 1932, pp. 25-38.

7/ I. B. Jchsnon and Lester E. Johnson, Fattening Range Lambs on South Dakota Feeds, South Dakota Agr. Expt. Sta. Bul. 373, 1944, pp. 11, 12.

TABLE 9. RATIONS FOR FATTENING WESTERN LAMBS USING ALFALFA HAY 1/

Item	Percentage of Concentrate in Ration 5	25	40	50	60
FIRST 10 LBS. GAIN					
Average Daily Ration					
Concentrates (lbs) 2/	---	.50	.7	.9	1.1
Protein Supplement (lbs)	---	---	.1	.1	.1
Alfalfa Hay (lbs) 2/	3.3	2.8	2.0	1.7	1.4
Days for 10 lbs. Gain	67	48	43	40	37
Daily Gain	.15	.20	.23	.25	.27
SECOND 10 LBS. GAIN					
Average Daily Ration					
Concentrates (lbs)	.2	.8	1.3	1.4	1.8
Protein Supplement (lbs)	---	---	.1	.1	.1
Alfalfa Hay (lbs) 2/	3.5	2.7	2.0	1.7	1.2
Days for 10. lbs. Gain	63	39	34	30	28
Daily Gain	.16	.25	.29	.33	.35
THIRD 10 LBS. GAIN					
Average Daily Ration					
Concentrates (lbs)	.3	1.0	1.4	1.7	2.2
Protein Supplement (lbs)	---	---	.1	.1	.1
Alfalfa Hay (lbs) 2/	3.6	2.7	2.0	1.6	.9
Days for 10 lbs. Gain	55	39	34	30	28
Daily Gain	.18	.25	.29	.33	.35
Slaughter Grade 3/	Utility-Good	Good Choice	Choice	Choice Prime	Prime
FOURTH 10 LBS. GAIN					
Average Daily Ration					
Concentrates (lbs)	.30	1.3	1.6	2.1	
Protein Supplement (lbs)	---	---	.1	.1	
Alfalfa Hay (lbs) 2/	3.7	2.5	1.9	1.3	
Days for 10 lbs. Gain	50	39	34	30	
Daily Gain	.20	.25	.29	.33	
Slaughter Grade 3/	Good	Choice	Choice Prime	Prime	

1/ Initial weight - 65 lbs.
2/ Includes hay wasted. Estimated to be 10 percent of total hay offered.
3/ 1951 Grades.

TABLE 10. RATIONS FOR FATTENING WESTERN LAMBS USING NATIVE HAY 1/

Item	Percentage of Concentrate in Ration 40	50	60
FIRST 10 LBS. GAIN			
Average Daily Ration			
Concentrates (lbs)	.6	.8	1.0
Protein Supplement (lbs)	.2	.2	.2
Native Hay (lbs) 2/	2.0	1.7	1.4
Days for 10 lbs. Gain	50	43	40
Daily Gain	.20	.23	.25
SECOND 10 LBS. GAIN			
Average Daily Ration			
Concentrates (lbs)	1.1	1.3	1.7
Protein Supplement (lbs)	.2	.2	.2
Native Hay (lbs) 2/	2.0	1.7	1.2
Days for 10 lbs. Gain	39	34	30
Daily Gain	.25	.29	.33
THIRD 10 LBS. GAIN			
Average Daily Ration			
Concentrates (lbs)	1.3	1.6	2.[illegible]
Protein Supplement (lbs)	.2	.2	.2
Native Hay (lbs) 2/	2.0	1.6	.9
Days for 10 lbs. Gain	39	34	30
Daily Gain	.25	.29	.33
Slaughter Grade 3/	Choice	Choice Prime	Prime
FOURTH 10 LBS. GAIN			
Average Daily Ration			
Concentrates (lbs)	1.4	2.0	
Protein Supplement (lbs)	.2	.2	
Native Hay (lbs) 2/	2.0	1.3	
Days for 10 lbs. Gain.	39	34	
Daily Gain	.25	.29	
Slaughter Grade	Choice Prime	Prime	

1/ Initial weight - 65 lbs.
2/ Includes hay wasted. Estimated to be 10 percent of total hay offered.
3/ 1951 Grades.

TABLE 11. RATIONS FOR FATTENING WESTERN LAMBS USING SUGAR BEET BY-PRODUCTS 1/

	Rations 1	2	3	4	5
Average Daily Rations					
Concentrates (lbs)	---	.2	.9	.9	.9
Protein Supplement (lbs)	---	---	---	---	---
Beet Tops (50% Moist.) (lbs) 3/	1.0	---	---	1.6	2.0
Wet Beet Pulp (lbs)	---	---	---	---	---
Dried Beet Pulp (lbs)	1.2	1.2	.9	.4	---
Alfalfa Hay (lbs) 2/	1.0	1.5	1.2	1.2	1.2
Daily Gain	.22	.22	.29	.29	.29
Number of Days	136	136	103	103	103
Grade	Good-Choice	Good-Choice	Choice Prime	Choice Prime	Choice Prime

1/ Initial weight - 65 lbs. Final weight - 95 lbs.
2/ Includes hay wasted. Estimated to be 10 percent of total offered.
3/ Beet top silage may be substituted for beet tops on pound for pound basis.

TABLE 12. RATIONS FOR FATTENING WESTERN LAMBS USING SUGAR BEET BY-PRODUCTS 1/

	Rations 6	7	8	9	10	11
Average Daily Ration						
Concentrates (lbs)	---	---	1.0	.7	.8	.2
Protein Supplement (lbs)	---	.2	.2	.2	.2	.2
Beet Tops (lbs) 3/	1.0	1.0	1.0	1.0	---	---
Wet Beet Pulp (lbs)	9.0	9.0	5.0	---	---	---
Dried Beet Pulp (lbs)	---	---	---	.7	.7	1.4
Alfalfa Hay (lbs) 2/	1.0	1.0	1.0	1.0	1.5	1.2
Daily Gain	.23	.26	.30	.30	.30	.30
Number of Days	131	116	100	100	100	100
Grade	Good-Choice	Choice	Choice Prime	Choice Prime	Choice Prime	Choice Prime

1/ Initial weight - 65 lbs. Final Weight - 95 lbs.
2/ Includes hay wasted or refused. Estimated to be 10 percent of total offered.
3/ Beet top silage may be substituted for beet tops on pound for pound basis.

V. INPUT-OUTPUT RELATIONSHIPS IN FEEDING HOGS

Input-output relationships for hog production deal mainly with feed input substitution. The amount of feed required to produce a particular gain is dependent to a large extent upon the quality of the feed input. Consequently, physical transformation data which will be useful for an economic analysis should present the rates of substitution for the feeds which are commonly fed to hogs.

The level of feeding affects the input-output relationships to limited extent. In general, experimental studies do indicate that some savings in feed results from limited feeding, but in view of the small differences in input-output relationships for the various levels of feeding, it does not appear practical to estimate the relationships. Also, these studies indicate that the slow gains and additional labor which are associated with limited feeding tend to more than offset the savings in grain 1/.

The market weight, or the length of the feeding period, also affects the input-output relationship 2/. The physical efficiency of gain decreases as hogs reach heavier weights. This difference is not too significant, however, if the feed required per pound of gain is expressed in feed units. Experimental studies indicate that hogs marketed at 200 pounds consume about .5 percent fewer feed units per 100 pounds of live weight than do hogs marketed at 225 pounds. Hogs marketed at 250 pounds require about 1 percent more, at 275 pounds about

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1/ F. B. Morrison, Feeds and Feeding, Ithaca, N. Y. Morrison Pub. Co., 21st Ed., 1949, pp. 969-970.

2/ L. J. Atkinson and J. W. Klein, Feed Consumption and Marketing Weight of Hogs, U. S. D. A., Tech. Bul. 894, July 1945.

2 percent more, and at 300 pounds 3 percent more feed units per 100 pounds of live weight than 225 pound hogs 3/. This small difference in feed requirement for the various market weights does not appear to justify a presentation of separate relationships for several market weights.

A great number of feed substitutions are possible in the feeding of hogs. For example, barley may replace corn, proteins may replace carbonaceous concentrates, animal proteins may replace vegetable protein, and alfalfa pasture may replace protein supplements. However, these substitution possibilities are not of equal importance. Corn is such a standard feed in hog production that it does not appear practical to present data on the rates of substitution within the carbonaceous concentrate group. In the protein supplement group, a mixture of 50 percent animal protein and 50 percent vegetable protein for feeding on pasture, and 50 percent animal protein, 25 percent vegetable protein and 25 percent ground alfalfa for dry lot feeding seems to be the most practical combination in terms of physical efficiency 4/.

The substitution of protein supplement for corn appears to be one of major importance in hog production. On pasture under various price relationships the most economical ration may vary from one which contains no protein supplement to one which contains 13 percent protein supplement.

3/ Ibid., pp. 8, 9, 25. The feed unit is the common denominator for all kinds of feeds and is equal in feeding value to 1 pound of corn. The feed unit value of 1 pound of principal hog feeds are: corn, 1.000; Soybean oil meal, 1.75; tankage 2.50. Since a smaller amount of valued feeds are required in the ration for efficient gain after the pigs reach a weight of 200 pounds, the increases in feed required per unit of gain for heavier market is not too great when expressed in terms of feed units.

4/ Morrison, op. cit., pp. 962, 963. Data are lacking to show the affect on gains if animal-protein is decreased below 50 percent.

Likewise, in drylot, the protein supplement content may vary from 2 to 25 percent of the total feed requirement. Other important substitutions are the alfalfa pasture for protein supplement and the skimmilk for protein supplements and corn. These substitution possibilities are discussed below.

Some rations for feeding pigs on good alfalfa pasture are shown in tables 13 5/. These feed inputs in this table represent the alternative combination of protein supplements and corn for producing 100 pounds of gain as the pigs are fattened from an initial weight of 30 pounds to a market weight of 180 - 230 pounds. At each level of protein feeding it is assumed that the protein supplement is fed in the most efficient manner, i.e., higher proportion of supplement is fed during the early growth period 6/.

Rations for drylot feeding of pigs is presented in table 14. The estimates are presented in the form of feed required per 100 pounds of gain for pigs fattened from initial weight of 30 pounds to final weight of 180 to 230 pounds. The protein supplement for the drylot feeding consists of 50 percent tankage, 25 percent vegetable protein and 25 percent ground alfalfa. The assumption on the distribution of the protein feed throughout the growth period is that the ration will contain a greater proportion of protein feed during the

6/ F. B. Morrison, op. cit. p. 944.

early growth stage 7/.

Rations for feeding pigs when skimmilk is available are presented in table 15. Skimmilk is a valuable protein supplement for feeding growing and fattening pigs 8/. Because of the watery composition of skimmilk and the inability of pigs to consume enough corn for efficient gains, the value of skimmilk decreases rapidly as the proportion of skimmilk in the ration is increased 9/.

7/ F. B. Morrison, Feeds and Feeding, Ithaca, N. Y., The Morrison Pub. Co., 20th ed., 1946, p. 852; W. E. Carroll and J. L. Krider, Swine Production, New York, N. Y., McGraw-Hill Book Co. Inc., 1st ed. 1950, p. 382; James W. Wilson and Turner Wright, op. cit. p. 33; Arthur H. Kuhlman and James W. Wilson, Improving Winter Rations for Pigs, South Dakota Agr. Expt. Sta. Bul. 216, 1925, pp. 5, 7; C. M. Vestal, op. cit. p. 7; E. J. Maynard, et al., Colorado Dryland Fattening Rations for Swine, Colorado Agr. Expt. Sta. Bul. 396, 1932, p. 18; John P. Willman and F. B. Morrison, Feeding Experiments With Growing and Fattening Pigs, New York Agr. Expt. Sta. Bul. 836, 1947, p. 15; idem, Protein and Vitamin Supplements for Growing and Fattening Pigs, New York Agr. Expt. Sta. Bul. 730, 1940, pp. 26, 34-35, 42; W. L. Robison, Improving Corn and Tankage for Pigs not on Pasture, Ohio Agr. Expt. Sta. Bul. 488, 1931, pp. 4, 12, 13, 15, 17, 19; idem, Substitutes For Corn For Growing and Fattening Pigs, Ohio Agr. Expt. Sta. Bul 607, 1939, pp. 29, 40.

8/ William W. Smith, et al., Pork Production, New York, N. Y., The Mac Millian Co. Revised Edition, 1937, pp. 303, 305; W. L. Robison, Improving Corn and Tankage for Pigs not on Pasture, Ohio Agr. Expt. Sta. Bul. 488, 1931, p. 19; L. A. Weaver, Pastures for Hogs, Missouri Agr. Expt. Sta. Bul. 247, 1927, p. 35; H. H. Smith and E. J. Maynard, Summer and Winter Rations for Hogs, Utah Agr. Expt. Sta. Bul., 1935, pp. 7, 12; F. B. Headley, Hog Feeding Experiments, Nevada Agr. Expt. Sta. Bul. 125, 1932, p. 22; Arthur H. Kuhlman and James W. Wilson, Improving Winter Rations for Pigs, South Dakota Agr. Expt. Sta. Bul. 216, 1925, pp. 5-7.

9/ Morrison, op. cit., (20th ed), p. 871.

TABLE 13. RATIONS FOR FEEDING PIGS ON ALFALFA PASTURE 1/

Protein Supplement: Tankage 3/ (lbs)	Protein Supplement: Soybean Oilmeal (lbs)	Feed Required per 100 lbs. gain 2/: Corn (lbs)	Total (lbs)	Av. Daily Gain (lbs)
0	0	442	442	.90
5.0	5.0	412	427	1.00
7.5	7.5	390	405	1.09
10.0	10.0	372	392	1.17
12.5	12.5	356	381	1.24
15.0	15.0	342	372	1.30
17.5	17.5	330	365	1.35
20.0	20.0	320	360	1.39
22.5	22.5	312	357	1.40

1/ Initial weight of pigs - 30 lbs. Final weight 180-250 lbs.
2/ Two pounds of mineral mixture required per 100 lbs. gain.
3/ Skimmilk may be substituted for the tankage only at a rate of 100 lbs. skimmilk for 15 lbs. tankage.

TABLE 14. RATIONS FOR FEEDING PIGS IN DRYLOT 1/

Protein Supplement: Tankage (lbs)	Protein Supplement: S.O.M. (lbs)	Protein Supplement: Gr. Alf. (lbs)	Feed Required per 100 lbs. gain 2/: Corn (lbs)	Total (lbs)	Av. Daily Gain (lbs)
5.0	2.5	2.5	650	660	.60
10.0	5.0	5.0	490	510	.95
15.0	7.5	7.5	437	467	1.07
20.0	10.0	10.0	411	451	1.14
25.0	12.5	12.5	389	439	1.21
30.0	15.0	15.0	369	429	1.26
35.0	17.5	17.5	351	421	1.32
40.0	20.0	20.0	335	415	1.37
45.0	22.5	22.5	323	413	1.38
50.0	25.0	25.0	311	411	1.39

1/ Initial weight of pigs - 30 lbs. Final weight 180-250 lbs.
2/ Four pounds of mineral mixture required per 100 lbs. gain.
3/ Skimmilk may be substituted for the tankage only at a rate of 100 lbs. skimmilk for 15 lbs. tankage.

TABLE 15. RATIONS FOR FEEDING PIGS ON SKIMMILK IN DRYLOT AND ON PASTURE

In Drylot: Skimmilk (lbs)	In Drylot: Ground Alfalfa (lbs)	In Drylot: Corn (lbs)	On Pasture: Skimmilk (lbs)	On Pasture: Corn (lbs)
150	48	426	150	360
300	44	365	300	315
450	39	306	450	289
600	34	256	600	263
750	32	214	750	248
1000	31	211	1000	245

Feed Requirement per 100 Lbs. Gain

1/ The average daily gain is 1.3 lbs. in all cases.
2/ Initial weight 30 lbs. - Final weight 180-230 lbs.

VI. INPUT-OUTPUT RELATIONSHIPS IN EGG PRODUCTION

The relationship between feed input and egg production is primarily dependent upon (1) the amount of feed consumed, (2) quality of the feed and (3) the breed of the hen 1/. This relationship is also affected by the inherent producing capacity of the hen, but available information is not sufficient for considering this factor in estimating input-output relationships. Furthermore, when a farmer purchases a flock of chicks, he is usually not certain of the producing ability of the pullets that are raised from these chicks. Therefore, estimates on input-output relationships were made for a hen of "average" producing capacity.

Experimental studies indicate that as the rate of feeding a hen is decreased from full feed--production decreases. Hansen's study shows that hens fed 90 percent of full feed produced only 70 percent as many eggs as those full fed 2/. Carlson also estimates that less feed is required per dozen eggs at full feeding than at various levels of limited feeding 3/.

The quality of the ration fed to hens for egg production is of great importance. The hen needs an ample amount of nutrients in order

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1/ Pete L. Hansen, "Input-Output Relationships in Egg Production", Journal of Farm Economics, Vol. 21, Nov. 1949, p. 692; Harry W. Titus, U. S. D. A. Yearbook of Agriculture, Food and Life, 1939, Washington, D. C. U. S. Govt. Printing Office, pp. 820-21; W. Ray Ewing, Handbook of Poultry Nutrition, New York, N. Y., J. J. Little & Ives Co., 1st ed., 1941, p. 802.

2/ Hansen, op. cit., p. 692.

3/ Suggested by Dr. C. W. Carlson, Poultry Nutritionist at South Dakota State College. This relationship suggests that the most profitable level of feeding is full feeding. The logical course of action for the producers if the feed-egg price relationship is not too favorable (i.e. more profitable use of feed can be made by feeding it to other livestock) is to sell part of the flock and full feed the remaining birds. There are cases, however, when limited feeding is the rational course of action. Such a procedure would be followed if the producer anticipated a rise in the price of eggs to a point where the grain-egg price relationship is favorable compared to alternative uses of feeds.

to maintain health, proper body weight and egg production. The ration should contain all essential vitamins, amino acids and minerals for maximum egg production. The most satisfactory sources of protein for hen rations are as follows (listed in order of value): dried skimmilk, dried buttermilk, fish meal, meat scraps soybean meal, cottonseed meal, and linseed meal 4/.

Ewing states that most commercially mixed and balanced rations are usually better for maximum egg production than home mixed feeds because they are more scientifically balanced, with better texture and palatability and usually contain all of the essential vitamins, amino acids and minerals 5/. The ration fed to laying hens should be palatable--otherwise egg production will drop because of decreased feed consumption.

Light breeds produced more eggs on less feed than heavy breeds. Waite's study shows that a light breed produced an average of one dozen eggs for each 4.8 pounds of feed consumed; a heavy breed produced an average of one dozen eggs for each 5.66 pounds of feed consumed, which is 17.81 percent more feed 6/. This difference in physical efficiency is sufficiently great to warrant estimating input-output relationships for both the light and heavy breeds.

The estimated effect of rate of feeding and ration on egg production for light and heavy breeds is presented in table 17. Estimates on annual feed requirement and egg production were made for 4 levels of feeding which range from 75 to 100 percent of full feeding. Three different

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4/ Titus, <u>op. cit.</u>, pp. 820-21.
5/ Ewing, <u>op. cit.</u>, p. 8.
6/ Roy H. Waite, <u>Feed Consumption Studies Based on the Six Maryland Egg Laying Contests</u>, Maryland Agr. Expt. Sta. Bul. 359, 1934, p. 329.

types of rations are used to show the effects of quality of ration upon egg production.

Ration "A" is a commercially mixed and balanced ration. More egg production can be expected with Ration "A" than Ration "B" which is a home mixed ration with most of the required ingredients for a good quality ration. Ration "B" has a greater percentage of corn and oats and less protein than Ration "A" which tends to make the "B" ration inferior to "A". Ration "C" is a simple ration which can be mixed quite readily on the farm. This ration is comparable to ration "B" in terms of annual egg production, but more pounds of feed are required.

The estimates in table 16 were made on the assumption that (1) average housing and (2) average management would be provided for hens of average producing ability.

RATIONS USED IN TABLE 16

Ration "A"

Scratch:	Whole Corn	17%
	Whole Oats	17%
Mash:	Wheat Shorts	25%
	Wheat Middlings	10%
	Yellow Corn Meal	10%
	Soybean Oil Meal	16%
	Meat Scraps	5%
	TOTAL	100%

Ration "B"

Scratch:	Whole Corn	25%
	Whote Oats	25%
Mash:	Wheat Bran	10%
	Wheat Middlings	10%
	Ground Oats	10%
	Ground Y. Corn	10%
	Meat Scraps	10%
	TOTAL	100%

Ration "C"

Scratch:	Whole Oats	50%
	Whole Corn	45%
Other:	Liquid Skimmilk (dried basis)	5%
	TOTAL	100%

TABLE 16. RATIONS FOR EGG PRODUCTION -- LIGHT AND HEAVY BREEDS 1/

Ration and Rate of Feeding	Annual Feed Requirement (lbs) 2/	Annual Egg Production (doz)	Feed Required Per Doz. Eggs. (lbs)
	LIGHT BREEDS		
Ration "A"			
100%	88.0	14.6	6.04
90%	74.2	11.9	6.23
80%	70.4	8.5	8.28
75%	66.0	7.3	9.00
Ration "B"			
100%	88.0	14.2	6.21
90%	74.2	10.8	6.90
80%	70.4	8.2	8.62
75%	66.0	7.1	9.32
Ration "C"			
100%	93.5	14.2	6.60
90%	84.2	10.8	7.83
80%	74.8	8.2	9.16
75%	70.2	7.1	9.92
	HEAVY BREEDS		
Ration "A"			
100%	97.9	13.6	7.21
90%	88.1	10.3	8.53
80%	78.3	7.9	9.89
75%	73.5	6.8	10.76
Ration "B"			
100%	97.9	13.2	7.43
90%	88.1	10.0	8.81
80%	78.3	7.7	10.21
75%	73.5	6.6	11.17
Ration "C"			
100%	103.4	13.2	7.85
90%	93.1	10.0	9.31
80%	82.7	7.7	10.78
75%	77.6	6.6	11.79

1/ Light breeds, 4-4½ pounds; Heavy Breeds, 5-5½ pounds.
2/ Figures include waste -- 10 percent of total offered.

VII. INPUT-OUTPUT RELATIONSHIPS IN BROILER AND FRYER PRODUCTION

The relationship between feed input and rate of gain is principally dependent upon: (1) the level of feeding; (2) level of protein in the ration; (3) quality of the ration; (4) sex and breed of the chickens. Each of these four points will be briefly discussed below.

Since restricted feeding results in unsatisfactory growth and impairs the health of the bird, estimates on various levels of feeding are not made for broilers and fryers 1/. The estimated effect of the level of protein in the ration on rate of gain is given primary consideration.

Good quality crude protein is the most important ingredient in chicken rations, especially when the birds are being grown for meat production. The amount of protein required varies at different stages of growth, but it can be said that the optimum level is about 17 percent as an average for all stages of growth 2/.

The quality of the ration is dependent to a large extent upon the quality and amount of protein in the ration. Proteins from animal sources are of higher quality than vegetable proteins for poultry production 3/. The effect of amount of protein in the ration has been discussed previously.

1/ Restricted feeding decreases the vitality of chickens and requires more time and more feed which suggests that the most profitable level of feeding is full feeding. The logical course of action for the producers, if the feed-meat price relationship is not too favorable, (i.e. more profitable use of feed can be made by feeding it to other livestock) is to sell part of the flock and full feed the remaining birds.

2/ J. S. Carver, et al., "Protein Requirements of Chickens", Poultry Science, Vol. 2, Jan. 1932, p. 45; Ewing. op. cit., p. 96; Jeffrey, op. cit., p. 9.

3/ W. Ray Ewing, A Handbook of Poultry Nutrition, New York, N.Y., J. J. Little & Ives Co., 3rd ed., 1947, pp. 96 & 158.

The heavy breeds are the most efficient for meat production. The light breeds are also used, but they are less efficient in rate of growth and do not command as high a price 4/. Heavy breeds of chicks require less feed than light breeds for each pound of gain. This difference in feed requirement is approximately 20 percent. Male birds of both light and heavy breeds gain faster and more efficiently than females 5/.

The estimated effect of the level of protein in the ration on rate of gain and feed requirement in the production of broilers and fryers is presented in table 17. Estimates on rate of gain and feed required were made for three different rations which contain varying amounts of protein.

Ration "A" is the most efficient in terms of feed required for a particular gain. This ration contains 17 percent protein which is considered the optimum level for efficient growth. Ration "B" contains 14 percent protein. This ration is inferior to ration "A" because of the lesser amount of protein and 8 percent more of this feed is required to produce a gain comparable to ration "A". Ration "C" is a simple ration which contains 11 percent protein. The ration can be made from farm grown feeds, but it is inferior to ration "A" and "B" as far as rapid growth and feed requirements are concerned. A comparison of ration "C" with ration "A" indicates that approximately 45 percent more feed is required when ration "C" is used. Also, chicks that are fed ration "C" require approximately two weeks longer to reach a weight comparable to the "A" feeding system.

4/ Ewing, op. cit., p. 13.

5/ Roy H. Waite, Broiler Production, Maryland Agr. Expt. Sta. Bul. 383, 1935, pp. 337-349.

RATIONS USED IN TABLE 17

Ingredients of Mash Rations

Ration "A" - 17% Protein 1/	
Ground Corn	35%
Wheat Bran	20%
Wheat Mid.	20%
Soybean Oilmeal	15%
Alfalfa Leaf Meal	5%
Meat Scraps	2%
Fish Meal	2%
Cod Liver Oil	.5%
Salt	.5%

Ration "B" - 14% Protein 2/	
Ground Corn	40%
Ground Oats	38%
Soybean Oilmeal	12%
Meat Scraps	5%
Alfalfa Leaf Meal	5%

Ration "C" - 11% Protein 2/	
Ground Corn	45%
Ground Oats	45%
Skimmilk (dry basis)	5%
Alfalfa Leaf Meal	5%

1/ This is considered a commercial ration. Any commercial ration which has the ingredients cited or the equivalent is applicable.

2/ These rations may be mixed on the farm. In addition to the requirement cited in the table, .2 lbs. of oyster shells and .1 lbs. of salt are required per bird. In ration "C" the skimmilk dry basis may be converted to skimmilk liquid basis by multiplying the amount by 10.

TABLE 17. RATIONS FOR THE PRODUCTION OF BROILERS AND FRYERS 1/

		Ration "A"		Ration "B"		Ration "C"	
	Weight (lbs)	Age (wks)	Mash (lbs)	Age (wks)	Mash (lbs)	Age (wks)	Mash (lbs)
Light Breeds							
(For Male Birds)							
Broilers	2.0	13.0	8.0	13.6	8.6	15.2	11.5
	2.5	14.5	9.6	15.1	10.4	17.0	13.9
Fryers	3.0	16.0	12.7	16.7	13.7	18.8	17.8
	3.5	18.5	17.7	19.3	19.1	21.8	25.5
(For Female Birds)							
Broilers	2.0	14.0	9.5	14.6	10.2	16.4	13.7
	2.5	16.0	12.5	16.7	13.5	18.8	18.0
Fryers	3.0	18.0	16.5	18.8	17.8	21.2	23.3
	3.5	20.5	22.5	21.4	24.1	24.2	30.6
Heavy Breeds							
(For Male Birds)							
Broilers	2.0	11.0	6.8	11.6	7.3	13.2	9.8
	2.5	12.5	8.5	13.1	9.2	15.0	12.3
Fryers	3.0	14.0	11.2	14.7	12.1	16.8	15.8
	3.5	16.5	15.9	17.3	17.0	19.8	21.3
(For Female Birds)							
Broilers	2.0	12.0	8.5	12.6	9.2	14.4	12.3
	2.5	14.0	10.9	14.7	11.7	16.8	15.6
Fryers	3.0	16.0	14.3	16.8	15.2	19.2	19.9
	3.5	18.5	19.7	19.4	20.7	22.2	26.2

1/ Feed requirements include waste - estimated to be 10 percent of total offered.

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